A

PRACTICAL METHOD,

To Discover the

LONGITUDE at SEA,

By a New Contrived

AUTOMATON.

Freed from all the Various Effects of *Air* in different *Climates*, *&c.* And not Liable to *Disorder* by the *Irregular Motion* of a *Ship.*

The whole Method Rendered *Plain* and *Easie* to be Understood by every *Mariner.*

With an

Account of the Author's new *Instrument* for taking the *Latitude* more *Accurately* at *Sea*, than hath hitherto been *Practised.*

Humbly Offer'd to the Consideration, and Use of the Publick.

By *JOHN WARD.* of *Chester.*
Author of the *Young Mathematician's Guide*, *&c.*

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BIBLIOTHECA BODLEIANA

To the Right Honourable the

LORDS

With the Reſt of the Honourable

COMMISIONERS,

Conſtituted and Impowered by *Act* of *Parliament*, to Receive, and Judge of, all PROPOSALS made to them, for *Diſcovering* the *LONGITUDE* at *SEA.*

This Tract Deſign'd for that *Diſcovery*, is Moſt Humbly *Submitted*,

and *Dedicated*,

By its Author

J. Ward.

The Reader is desir'd to Correct these Errors in the Preface.

PAge the Firſt, Line 23, inſtead of 79th, Read 29th. And Page the Fourth, Line 14, inſtead of, *did fall*, Read *did not fall.* And if there be any Literal Faults in the whole, tis hop'd he will paſs them over.

The PREFACE.

Courteous Reader,

HERE is Submitted to thy Cenſure, a ſmall Tract, which (altho' the Subject be Difficult,) I hope will Anſwer its Title; 'twas deſign'd to have been Publiſhed in *September* laſt, but when I came to the finiſhing Stroak I found it very requeſite to Calculate New Correct *Tables* for the *Æquation* of *Time*, in order to render the Work more Compleat and Uſeful in *Practice*.

And I then thought it would be Proper, to preſent every one of the *Honourable Commiſſioners (Nam'd in the Dedication,)* with a fair Copy of the whole Method, before it were Printed; and accordingly I prevailed with a Friend to undertake the Tranſcribing of thoſe Copies, which proving Tedious, and unforeſeen Buſineſs preventing him, I was forc'd to let that deſign Drop; and ſent the Manuſcript to be Printed off: Where (*not being able to attend the Preſs my Self,*) it has been farther Delaid by the Printers Neglect, or it had appeared in Publick above Three Months ſooner.

Whilſt it Laboured under theſe Diſappointments, a Pamphlet was Publiſhed (in *November*) by one *Jer---y Th--ker*, Entituled, *The Longitudes Examin'd*, &c. which came to my Hands the 29th of that Month; and gives the Occaſion of Writting this Preface, with the following Affidavit; for when I found that Author propoſed a Machin to Move in a Glaſs Receiver, as a means to Diſcover the Longitude; I had Reaſon to Suſpect, as well from private Circumſtances, as from the Crude indigeſted Notion he ſeems to have (*by his imperfect Application,*) of ſo Uſeful a thing as a Recipient rightly Appli'd, will undoubtedly prove; That the Knowledge he pretends to have in this Affair, came by *Trap*, and not the way he ſo Boaſtingly tells the World of thus.

It is now (ſaye he,) *well nigh towards half a Tear*, (which by the Way is near the Time I Ground my private Suſpicion

ſpicion on,) *ſince My Good Genius, and my Self, found out a Method for Diſcovering the Longitude, the Secret that Nature had Confeſs'd to* ME, *and had refuſs'd to* THEM, (meaning the Longitudinarians,) *as often as they have ask'd her for it.*

Boldly ſaid Mr. *Th---ker.* But upon the Peruſal of what follows, *(I humbly Conceive,)* you'l find your Miſtake, in preſuming to be Natures only beloved Darling.

A True Copy of an Affidavit, made by one of the Common Council of the City of *Cheſter*; before *Francis Sayer* Eſq; Mayor. *Roger Comberbach* Eſq; Recorder. *Peter Bennet*, and *James Mainwaring* Eſqrs; Juſtices of the Peace, and Aldermen of that City.

WIlliam Bird *Citizen of* Cheſter, *Voluntarily maketh Oath, that in the Month of* July, 1714. *This Deponent being at Mr.* John Ward's *Chamber in the ſaid City of* Cheſter, *there happened ſome Diſcourſe between the ſaid Mr.* Ward *and this Deponent, concerning the Great Reward, which the Parliament had then Newly Settled upon any Perſon, who could Diſcover the* Longitude *at* Sea; *And the ſaid Mr.* Ward *then told this Deponent, that he the ſaid Mr.* Ward, *ſome Years ago, (when he lived in* London,) *had ſome thoughts about Diſcovering the* Longitude, *and that he verily Beleived he had at that time found out a Method that would Diſcover it at Sea; But the ſaid Mr.* Ward, *being (as he ſaid,) then much Indiſpoſed in his Health, was adviſed to leave* London, *and repair to his Native Country, to try what effects that Air would have towards Recovering his Health, and ſo he let the thoughts of it Drop for that time, and ſeveral other Diſcourſes upon the ſame Subject paſſed betwixt the ſaid Mr.* Ward *and this Deponent.*

And this Deponent farther ſaith, that the ſaid Mr. Ward *then asked this Deponent, whether he could keep a Secret, to which this Deponent replyed, that he both could and would if it were Enjoyned him by the ſaid Mr.* Ward. *Whereupon the ſaid Mr.* Ward *told this Deponent, that the* Longitude *might be found by an exact Movement to be made in ſuch Manner as he the ſaid Mr.* Ward *would Deſcribe,*

and

and that to Move in Vacuo would do it, for thereby it would be freed from all the Various effects of the Air; upon which this Deponent desired the said Mr. Ward *to Recollect his Thoughts on that Subject, and prepare them for Practice, and this Deponent farther saith, that the said Mr.* Ward *in a few Days after set about the said Work, and in* September *following, was so Farward in the said Method, that he Employed this Deponent to Transcribe a fair Copy of what he the said Mr.* Ward *had then Wrote, in Order to present the same to the Commissioners, before he Published the same in Print, (as he told this Deponent,) and this Deponent farther saith, that he Transcribed the said Copy, for the said Mr.* Ward, *to the Twenty Sixth Page, in a Large Octavo, and that the same Consisted of a short Introduction, some Definitions, a Description of the Movement and manner of Placing it in Vacuo, with Answers to such Objections as the said Mr.* Ward, *(said,) he supposed might be Raised against its Use at Sea, and several other Particulars, and this Deponent farther saith, that he then Understood by the said Mr.* Ward, *that he Intended to Calculate some Tables that were needful to Render the Work Compleat, which this Deponent takes to be the Reason, why the said Mr.* Ward's *Book was not Printed so soon as was at first Intended. And this Deponent farther saith, that there having been a Book Published in* November *following, by one* Jeremy Thacker *of* Beverly *in* Yorkshire, *which he the said Deponent hath seen, wherein that Author mentions a* Machine, *kept in a Vacuum as a Means to Discover the* Longitude *at* Sea, *this Deponent is therefore desired to Make and Publish to the World this Affidavit of the Truth of the Above-mentioned Particulars.*

William Bird.

Jurat apud Civit Ceſt. Viceſimo die Decembris, Anno Regni Domini Georgii Regis, Magnæ, Britannæ primo. Coram.

Francis Sayer, Mayor.
Roger Comberbach, Recorder.
Peter Bennet.
James Mainwaring.

By

The PREFACE.

By this time I hope the Impartial Reader is pretty well Satisfied, whether Mr. *Th--ker*, or *J. Ward* did firſt Project the Uſefulneſs of a Recipient for the preſent Purpoſe, and when he has perus'd the following Pages, I believe he will then be fully Satisfied, which of us hath arrived the neareſt to the Perfecting of that Thought; not only in Freeing any Time-keeper from the various Effects of Air, *&c.* But alſo, the Method of Applying the Time ſo kept, to the Practical Diſcovery of the Longitude at Sea; without which the Time-keeper will be of very little Uſe. Now this part of Compleating the Work, Mr. *Th---ker* is ſo far from Performing, that he does not Vouchſafe ſo much as to Undertake it: *(No, no, that Part did fall into the Trap.)* And yet he often poſitively aſſures himſelf to carry off the *Twenty Thouſand* Pounds.

For my Part, I have done every thing that I can Immagine is neceſſary to Accompliſh the Deſign; And altho' I am now *Depreſs'd* with *Age*, and have had a long *Indiſpoſition* of Body, *&c.* Yet (*Bona fide,*) I do not ſo much Covet the Reward, as the Satisfaction of being Uſeful to my Country, in Contributing all I can to the Induſtrious Mariners Endeavours; for *Improving* the *Art* of *Navigation*, which I hope will futher Appear in another Diſcourſe upon that Subject, (*if Encourag'd to it,*) wherein they will be fully Satisfied, that I am

Their Real Friend,

and humble Servant.

CHESTER,
January the 10*th,*
1714.

J. Ward.

A

A PRACTICAL METHOD, To Diſcover the LONGITUDE at SEA.

THAT a Practical *Method* of *Diſcovering* the *LONGITUDE* at *Sea*, hath been much wanted and earneſtly deſired by all Trading Nations, for improving the *Art* of *Navigation*, is very evident from the many *Eſſays* which have been made by ſeveral Eminent *Mathematicians* to accompliſh the ſame, (*particular Accounts thereof are to be ſeen in the Philoſophical Tranſactions*,) all of them true in *Theory*, but either ſo Abſtruſe, or attended with ſuch Difficulties, as have hitherto render'd them Impracticable at Sea.

It may therefore be *Humbly preſum'd*, that whoſoever ſhall Publiſh a Practical Method, for finding the ſaid *Longitude* to ſufficient Exactneſs, and eaſie to be Underſtood by every Practitioner, may have the Satisfaction of a favourable and kind Reception, from all who are to *Judge*, or make Uſe of it. And altho' the natural *Obligations* that all Men lie under, to promote the common good of *Society*, and the *Reputation* any *Perſon* may reaſonably propoſe to himſelf, by being either the *Author*, or the *Improver* of ſuch a Diſcovery as hath Employ'd the Thoughts of many Learned Perſons, are very prevailing, and undeniable Reaſons, why ſuch a Diſcovery, or Improvement, ſhould be Communicated to the Publick, if no other Reward were Propoſed; yet, ſince the *Legiſlative Authority* of this *Kingdom*, have Thought fit to Settle a very generous Reward, as an Encourage-

ment for ſo *Uſeful* and *Beneficial* a Work, it is hop'd, that any Perſon who Anſwers the End required, may take the Benefit of what is Offered, without the Imputation of doing it for that Gratuity only.

Now, in Order to render the Contents of this *Tract*, as Intelligible as the Nature of the Subject will Admit, it may be Convenient to begin at the very *Foundation*; *viz.* with a brief *Deſcription* of the *Earth*, and of a few ſuch *Lines* or *Circles*, upon which the true knowledge of both the *Latitude* and *Longitude* depends; For altho' the true Nature and Uſe of all ſuch *Imaginary Lines* and *Circles*, as are ſuppoſed to be in the *Heavens*, for Solving the *Phænomena* of the *Sun*, *Moon*, and *Stars*; And alſo thoſe ſuppoſed to be upon the *Surface* of the *Earth* and *Sea*, for the better Determining the *Scituation* of Places, in Reſpect to their *Latitudes*, and *Longitudes*, *&c.* are well known to the Skilful in *Mathematical Learning*, (who 'tis hop'd will Indulge the Author in this way of Proceeding, tho' it be Needleſs to them,) yet becauſe this *Tract* may fall into the Hands of many very *Ingenious Perſons*, who have not heretofore made any Enquiry into the Nature and Uſe of thoſe *Circles*, *&c.* but upon this Occaſion perhaps their *Curioſity* may Incline them to be Deſirous of ſeeing ſome ſhort and plain Account of the true Ground and Meaning of this difficult *Problem* of finding the *Longitude*, which is here Treated of, (*and at this Time makes ſuch a great Noiſe in the World,*) that ſo they may be the better prepar'd to Underſtand it, and its *Solution*; therefore in Favour of ſuch, and that it may be clearly Apprehended by all Perſons, even by the ordinary Seamen into whoſe Hands it may, (and hope it will) come; I ſhall therefore begin with;

A brief *Deſcription* of the *Earth*, *&c.*

THE whole *Earth* and *Sea*, taken together, do Compoſe or make up one intire *Spherical Body*, uſually called the *Terraqueous Globe*; and exactly thorow the *Middle* or *Center* of this *Globe*, there is imagin'd to paſs a *Right-Line*, called its *Axis*, the ends of this

this Axis (*ſuppos'd to be continued to the Heavens,*) are thoſe Two *Points* called the *North* and *South* Poles, whereon, (*or about which,*) the *Heavens*, with all their *Furniture*, apparently perform their *Diurnal Motions* from *Eaſt* to *Weſt*. And upon the Surface of this Earthly Globe, there are imagin'd ſeveral Circles of great Uſe; but I ſhall Deſcribe only ſo many of them as are moſt Uſeful for the preſent Purpoſe,

Viz. The *HORIZON*, the *EQUATOR*, and the *MERIDIAN*.

1. The *HORIZON* is a great *Circle* that *Divides* the Spherical Surface of our Earthly Globe into Two equal Parts, *viz.* the Upper or *Light Hemiſphere*, and the Lower or *Dark Hemiſphere*; and this is evident to any Perſon that will ſtand upon an open Plain, (*as upon the Sea, &c.*) in a clear Day, and look Round about him, he may then ſee a Circle, which Terminates his Sight, where the *Heavens* (*or Sky*) and Earth part, that's the *Viſible Horizon*, whereon the *Sun*, *Moon*, and *Stars* do (*Apparently*) *Riſe* and *Set*; The Place where the Obſerver ſtands, is its *Center*, and the Point in the *Heavens* juſt over his Head, is called the *Zenith*, from whence if a *Right-Line* be ſuppoſed to Paſs through the Center of the Earth, to the oppoſite Point in the *Heavens*, juſt under his Feet, that Point is called the *Nadir*; and theſe Two Points are Termed the *Poles* of the *Horizon*.

Hence, (*I preſume*) it will be eaſy to Conceive, that there are as many Horizons, as there are Different Places upon the Surface of the *Terraqueous Globe*.

2. The *EQUATOR* (or *Equinoctial-Line*, is a great Circle that Divides the Surface of the *Earth* and *Sea* into Two equal Parts, called the *Nothern*, and *Southern Hemiſpheres*, and is an *Invariable Circle* equally diſtant from both thoſe Poles, (*which are indeed its Centers*;) And therefore, the *Equinoctial* hath always the ſame equal Motion from *Eaſt* to *Weſt*, as the Heavens have, being that *Circle*, by which *Time* is truly *Meaſured*, *viz.* The *Hours* and *Minutes*, *&c.* which

the Sun (*apparently*) takes in its Daily Motion round the World; And for that Reaſon the 360 *Degrees* of the *Equinoctial*, are by ſome Authors called *Tempora* (or *Times*,) which being Divided into 24 equal Parts, (*the Hours in a Natural Day*,) every one of thoſe Parts will be *Fifteen Degrees* for the Meaſure of an Hour; conſequently every *Degree* of this Circle is the Meaſure of *Four Minutes* of *Time*.

3. The *MERIDIAN* is a great Circle that Paſſes through the Two *Poles* of the *Equator*, and the *Poles* of the *Horizon*, interſecting or *Croſſing* both the *Equator* and the *Horizon* at *Right-Angles*, and Divides the Surface of the Earthly Globe into Two equal Parts, called the *Eaſtern* and *Weſtern Hemiſpheres*; and is that Circle (*or Line*,) upon which the Sun is every Day juſt at *Noon*; *viz.* when it is exactly Twelve a Clock in the Place that lies under that *Meridian*.

Conſequently there are as many *Meridians*, as there are Places in the World that lie never ſo little diſtant One from Another, either towards the *Eaſt* or *Weſt*. Or rather, there are as many Meridians, as there are *Moments* of *Time*, in a Natural Day, or 24 Hours; becauſe the *Sun* is continually Moving every *Moment* of *Time*, from one *Meridian* to another *Weſtward*. All theſe Meridians meet at the *North* and *South* Poles.

4. The *LATITUDE* of any Place, either at *Land* or *Sea*, is the Diſtance of its *Zenith* from the *Equinoctial*, in *Degrees* and *Minutes*, &c. counted upon the Meridian, either *North* or *South*, according as the Zenith of the Place is in the *Northern* or *Southern Hemiſphere*, (viz. *on the* North *or* South *ſide of the Equinoctial*,) and that *Arch* of the *Meridian* included between the *Zenith* of any Place, and the *Equinoctial*, is always equal to the *Arch* of the ſame *Meridian*, included between the *Pole* and the *Horizon* of that Place; And therefore the *Latitude* is very often called the *Elevation* or *Height* of the Pole.

Now, becauſe the *North* and *South* Poles are fixt Points, and the *Equinoctial* an *Invariable Circle*, equally diſtant

diſtant from thoſe Points, it follows, that the *Latitude* of any Place is certain; and eaſy to be found by having the *Sun's* (*or any known fixt Stars,*) *Meridian Altitude*, and *Declination* given But the Sun's Meridian Altitude may be found by an Obſervation, made with a proper *Inſtrument* for that Purpoſe.

At preſent, that called *Daviſſe's Quadrant*, is moſt approved of and uſed at Sea, tho' it's not free from *Material Objections*; as the Difficulty of removing the *Sight Vane* to its true Place in the Time of Obſervation; Alſo, it is very Difficult to get a true *Sight* of the *Horizon*, if the Weather be never ſo little *Hazy*, and even in clear Weather, it is ſomewhat hard to Diſtinguiſh the Line, where the *Horizon* cuts the *Water*, which lays a great Streſs or Strain upon the *Eye* of the Obſerver. Theſe unavoidable Difficulties, (*to Name no more,*) attend the uſe of that Quadrant, and render the Obſervation uncertain; conſequently the *Latitude* which depends upon it, muſt be ſo too. And this I've often heard complain'd of, by very Ingenious *Navigators*, who have heartily Wiſh'd ſome more certain Way could be found for taking the Sun's Altitude at Sea.

Complaints of this *Defect* are to be met with in ſeveral Books of Navigation, I ſhall name only that of Mr. *Collins's*, *Entituled* the *Mariner's Plain Scale* new *Plain'd*, wherein, (*Page* 4.) Mentioning the Imperfections and Defects in the Art of Navigation; Laſtly (*ſaith he,*) the Obſervation of the *Latitude*, (*being the ſole help, whereby to Rectify an Erroneous Reckoning,*) cannot be performed ſo near the Truth, but that divers Minutes of *Error* will be Committed. He then gives this *Inſtance*; Six ſeveral Perſons at the ſame time in one Ship, who were Accuſtomed to *Obſervations*, and who for the moſt Part of them, had been more than Once at the *Eaſt* and *Weſt-Indies*, Obſerving the *Latitude*, did all Differ, ſome 13, ſome 27, and ſome 51 *Minutes* one from Another. Alſo, Mr. *Whiſton* and Mr. *Ditton*, in their New Method for *Diſcovering* the *Longitude*, find Fault with the *Inaccuracy* of the *Latitude*, as it's commonly taken. *Vide page* 17.

But

But now, all the aforeſaid Difficulties and Complaints may be wholly laid aſide, if the honeſt *Marriner* pleaſe to make Uſe of an *Inſtrument* that *I've Contrived* not long ago, and ſent a *Deſcription* thereof, (*viz. the manner how it muſt be made,*) to the *Ingenious Artiſt* Mr. *John Rowley, Mathematical-Inſtrument-Maker,* under St. *Dunſton's-Church* in *Fleet-Street, London.* There any Perſon may have that *Inſtrument* moſt accurately made, which will, (*I preſume,*) be found very uſeful and exact for taking Obſervations of the *Sun's Altitude* at Sea, even in *Hazy* Weather, when the *Sun Shines,* tho' but Faintly, and the *Horizon* not to be ſeen at all; conſequently the *Latitude* may be more frequently found, and with greater Certainty than heretofore, which muſt needs be a conſiderable Advantage in the Expedition of moſt (*eſpecially Long*) Voyages. And therefore, I hope it may juſtly be call'd a good Improvement to the Art of Navigation.

N. B. *By this New Inſtrument, the Sun's Altitude may alſo be very Nicely taken at Land, which cannot be done by* Daviſſes *Quadrant.*

5. The *LONGITUDE* of any Place, either at *Land* or *Sea,* is the *Horary Diſtance* of its Meridian, either *Eaſtward* or *Weſtward* from the *Firſt* Meridian, where the Account of *Longitude* is *Aſſign'd* to begin, and that Diſtance between thoſe Two Meridians makes an *Angle* at the *North,* and *South Poles,* (*where all the Meridians meet,*) that Angle being the ſame in all *Parallels* of *Latitude,* and is Meaſured by an *Arch* of the *Equinoctial,* call'd the *Difference* of *Longitude* between thoſe Two Meridians, (*or the Places that lie under them.*) Now, becauſe the *Motion* of the *Equinoctial* is the True and equal Meaſurer of Time, and that the *Difference* of *Meridians* is Meaſured by the Motion of the Equinoctial, and cannot be otherwiſe truly Meaſured; It will be eaſy to Conceive, that, if the *Time* which the *Sun* takes in its *Motion,* between any Two Meridians can be truly known; then the *Difference* of Longitude between thoſe Two Meridians is conſequently known,

by

by converting that *Time* into *Degrees* and *Minutes* of the Equinoctial; And therefore, all the *Methods* that have been formerly propoſed, (*or I preſume that can be Propoſed,*) to Diſcover the Difference of Longitude, between any Two Places, muſt neceſſarily depend upon the Knowledge of the *True Moments* of *Time*, in both thoſe Places.

As for Inſtance in the following Methods.

If by the *Eclipſes*, either of the *Sun*, or *Moon*,

Or, by the *Moon's Eclipſing* ſome of the *Fixed Stars*, that Lye in her *Path* or *Courſe*.

Or, by the *Revolution* of *Jupiter* upon his *Axis*.

Or, by the *Immerſions*, and *Emerſions* of *Jupiter's Satellits*, into, or from his Shadow, (*called their Eclipſes.*)

In all theſe *Phænomena*, the *exact Moments* of *Time* muſt be known, both in the Place for which the Calculations of thoſe Appearances are made, and in the Place of Obſervation where they are ſeen, or otherwiſe, the *Horary Diſtance* between the Meridians of thoſe Two Places, (*which is their Diſtance on the Equinoctial, or Difference of Longitude,*) cannot be Truly known.

Alſo, the *New* propoſed *Method* of finding the Longitude, by the *Motion* of *Sound*, &c. intirely depends upon the Knowledge of the exact Moments of Time, both in the Place where the *Exploſion* is *Made*, and in the Place where it is *Heard*.

It muſt be granted, that all theſe Methods to Diſcover the Longitude, are true in *Theory*, but attended with ſuch Difficulties in Practice, as render them uſeleſs at Sea, where I believe, (*nay, may venture poſitively to Affirm,*) that the Difference of thoſe Times, (*abovemention'd,*) cannot be Found, (*both at the ſame time,*) without the Aſſiſtance of an *Artificial Movement*, made either by Wheel-Work, or ſome other Contrivance equivalent to it. But if ſuch a *Movement* can be ſo made, as to become uſeful at Sea; then the *Difference* of *Longitude* between any Two Places (*or Meridians,*) may be found by it only, and that more Eaſily than by any other Method whatſoever.

And

And this the *Famous* Mr. *Huggens*, was in Hopes he had fully Accompliſhed, when firſt he Apply'd the *Pendulum*, to *Regulate* the Motion of *Clocks* and *Watches*, as plainly Appears by his Application made to the *States* of *Holland*, for the Recompence ſet apart for the *Invention*, in Caſe of Succeſs in Diſcovering the *Longitude* at *Sea*. (Vide. *Phil. Tranſ. Abridg'd. vol. the Firſt, page* 644.) From whence its evident, that *Ingenious Perſon* did not fore ſee ſuch Inconveniences as thoſe *Movements* were then *Liable* to at *Sea*; And, which are now become the common and moſt prevailing *Objections* againſt the uſe of all Movements there, that are made by Wheel-Work. *viz.*

The *Viciſſitudes* of the *Air* in different *Climates*, and *Seaſons* of the *Year*, in reſpect to its *Rarity*, *Denſity*, *Moiſtneſs*, *Drought*, *Heat*, and *Cold*; alſo, the *Irregular* Motion which a *Ship* has at *Sea*, but above all the *Influence* which the *Saline Effluvia* or *Particles* of Sea Air have upon *Metals*, in cauſing them to *Ruſt*, *&c.* in a very little Time.

Now if theſe *Effects* of the Air, (*which are all the Objections I know, or ever heard of*,) can be ſo provided againſt, by any Contrivance, as to have no Power over a Movement at Sea; Then I humbly Conceive, that finding the *Longitude* by an *Automaton*, will take Place before all other Methods, and this I hope will be Perform'd to all *Intents* and *Purpoſes*, by what I ſhall here Offer, when put into Practice.

A *Diſcription* of the propoſed *AUTOMATON.*

THE *Frame* of the *Movement* ſhould be at leaſt Six Inches Broad, and its height the ſame, that ſo the *Diviſions* on the *Dial-Plate* may be ſeen diſtinct and plain. The Firſt, or *Inner Circle* thereon, next the *Center*, is to be Divided into *Twelve* equal Parts, (*or Hours*,) and every one of thoſe into *Four* equal Parts (*or Quarters*,) to which the *Index* muſt Point, as in common *Clocks*. The next or outward *Circle*, is to be Divided into *Fifteen* equal Parts, and its *Index* to move Round that Circle every *Quarter* of an *Hour*; conſequently

quently that *Index* will ſhew the *Minutes* of Time; every one of thoſe *Minutes*, I would have *Subdivided* into other *Fifteen* equal Parts, then will the ſame *Index* as it moves over the Minutes, ſhew every *Four Seconds* of *Time*, which is equal to one Minute of a *Degree* in the *Equator*. That is, this laſt *Index* will by that Means paſs over 21600 of thoſe ſmaller Diviſions in a *Natural Day*, or 24 Hours, and juſt ſo many Minutes or Geographical Miles are contained in the 360 *Degrees* of the *Equator*. (*viz*. 360 x 60 = 21600 *the Minutes or Miles in a great Circle*.)

The *Inner* parts of the *Movement*, as the *Fuſy*, the *Main-Spring*, the *Chain*, and *Wheels*, I would have them all made in full Proportion to the *Size* of the *Frame*; And their Motion to be Govern'd by a pretty Weighty *Round Ballance*, and that to be *Regulated* by Two *Spiral Springs*, which muſt be ſo fitted to the *Verge* of the Ballance, as to *Bend*, and Unbend Alternately, *viz*. Whilſt one of thoſe *Springs* is Folding up by the Motion and Force of the Ballance, the other Spring muſt be at *Liberty* to unfold it Self; and by that Means thoſe Two *Springs*, being well *Adjuſted* to perform their Office, will keep the *Ballance* to a very Regular *Motion*, not much, (*if any*,) Inferior to that of a *Long Pendulum*, and in ſome Reſpects to be Prefer'd before it.

For, if ſuch a *Movement* be carefully and accurately Made, by an *Ingenious experienc'd Artiſt*; it will go equally alike in all Poſitions, *viz*. either *Horizontal*, *Perpendicular*, or *Reclining*, &c. which *Pendulum Movements* cannot poſſibly do. Nor will it be Subject to any Diſorder, by the Irregular Motion of a *Coach*, or that of a *Ship* at *Sea*. And being once well adjuſted to keep *Time*, which it may be brought to do in a Month or Two, with a few Trials made by the help of an *Æquation Table* of *Natural Days*, and a True *Meridian-Line*, drawn upon a Covenient plane for that Purpoſe. The way of doing both ſhall be ſhewed in its proper Place further on.

Note, *The making of this Movement is already well known, to that excellent Artiſt Mr.* Richard Street, *Clock-*

Maker, at the Dial, *and* Two Crowns, *over-againſt St.* Dunſtan's-Church *in* Fleet-Street, London.

The propoſed *Automaton* being thus made, the next Thing will be to ſhew how it may be *Freed*, and *Secured* from all the before-mentioned *Objections*, againſt its being uſeful at Sea. And that (*I preſume*) will be *Effectually* done, by the due Application of an *Univerſal Maxim*, in *Natural Philoſophy*.

Viz. *If the* Cauſe *of any* Effect *be taken away, the* Effect *produced from that Cauſe will* Ceaſe.

Which I thus Apply to the preſent Caſe.

LET a Strong Glaſs *Recipient* or *Receiver*, be made Large enough to Contain the *Automaton*, and ſo Contrived within, that the ſaid *Movement* may conveniently be Placed, and ſteadily Fix'd or faſtened in it, without Danger of Breaking the *Recipient*; the which being done, and all things Relating to it, well ſecured from the Force of Air, as the great Mr. *Boyle* uſed to do, in Trying his Experiments, *&c.* Then, Let the *Air* be *Exhauſted* or Drawn out of that *Receiver*, by a *Pneumatick Engine* or Air *Pump*, prepared according to the Neweſt Improvement of it, by the late *Ingenious* Mr. *Hawksbee*, who Lived in *Wine-Office-Court*, in *Fleet-ſtreet*, *London*. Then will that *Movement* be in a ſort, (*if not perfectly ſo,*) of a *Vacuum*, or at leaſt, where it will be Freed from all the various Influences of its great Enemy the External Air; nor can the *Æther*, which remains in the *exhauſted Receiver*, have any Power over its *Motion*. For the Curious Mr. *Boyle* ſays, He found by ſeveral Nice Experiments, that the *Æther* or *Subtle* Matter, which ſucceeds in the Place of the exhauſted *Air*, is neither *Hot*, *Cold*, *Moiſt*, or *Dry*: If ſo, then it ſeems to me very Rational to believe, (*and I humbly Hope it will be found true in Fact,*) that when once the Movement has been truly Adjuſted, to keep *equal Time* in the exhauſted Receiver, it will always have a more Regular Motion therein, (*during the Time of its being in Motion,*) than it can have out of the Receiver. And this Opinion is Grounded upon an Experiment that the ſaid Mr.

Boyle

Boyle made of a *Pendulum's Vibrating* in his exhausted Receiver, which, (*says he*,) Moved as Long, and Just, as Fast, as in the open Air. (*Vide Machina. Pneumat. Experi.* 26.) But the Automaton may continue, and be secure in the Receiver, as long as it is design'd to Go at once Winding Up, *viz.* either a *Week*, a *Month*, or a Quarter of a *Year*, or indeed as Long as you please. For whoever Reads over Mr. *Boyle's* Experiments, will find, that he kept several things in his *exhausted Receivers*, not only a *Month*, or *Quarter* of a *Year*; but some times a whole *Year*, or Two, nay Three *Years* together, without any Admission of the *External Air*.

But notwithstanding all that has been here said, to confirm the *Utilitie* or *Usefulness* of a *Recipient* in Freeing, and Defending the Automaton from the *Vissitude* of *Air*, &c. yet 'tis possible some Persons will Raise a few Objections against its Use at Sea.

1. *Objection.* A Glass Recipient seems to be a very improper thing to be made Use of on Ship-Board, for the designed purpose, because it must needs be often exposed to several Accidents, that may Indanger its Breaking; And if it Chance to be Broken, then the *Discovery* of the *Longitude* is over for that *Voyage*. To this I *Answer*, Let a Case be Neatly made of *Fine Copper*, for the Recipient, of the same Shape, and a small matter Bigger, that it may Admit of being Lined within, either with Two or Three Folds of soft *Flannel*, or Quilted with Cotton-Wooll, so as to be just fit to Cover the Outside of the Glass; And let it have an open Place in one Side of it, that the *Dial-Plate* of the *Automaton* may be all *Clearly seen*, without taking the Case off; Also, let the Bottom part of it be so Contrived, that when it is upon the *Glass*, it may be *Screw'd* fast down to the Board, upon which the *Recipient* must stand, when that is done the *Recipient* will then be Effectually secured from Breaking.

Or, suppose a *Recipient* were made of *Fine Copper*, (*or any other convenient Metal*,) free from Cracks and Flaws, &c. (*Large enough to Place the Movement in, &c. as before*,) and one Side of it to have a Round open Place, so Wide as to hold a *Meniscus Glass* in, (*viz. like*

that of a Pocket Watch,) about Six Inches Diameter, that ſo the *Dial-Plate* of the *Automaton*, may be all clearly ſeen at any Time, as well as in a Glaſs Recipient, then if that *Meniſcus Glaſs* be Titely Fitted, and ſecurely Cemented into the *Metal Recipient*, ſo that no *Air* can get in, I cannot ſee any Reaſon why it ſhould not be equally Uſeful for the preſent Purpoſe, with a Glaſs Recipient; therefore any Perſon may pleaſe his own Fancy in the Choice of either. Not, but that I ſhould rather Chooſe one made of Glaſs, with its Copper Cover.

2. *Objection.* It will be found very Difficult (*if not impoſſible,*) to preſerve the *Mercurial-Gage* at Sea, from being Broken, conſidering the *Poſition*; it muſt neceſſarily be fixt into the *Pneumatick Engine*, in order to ſhew, to what Degree the Recipient is exhauſted or freed from Air.

Anſwer. 'Tis true, that a *Mercurial-Gage* fixt to the Engine, in its uſual Poſition for trying Experiments, would moſt certainly Require a very great deal of Care to preſerve it, from being Broken at Sea. But I cannot perceive there's any Occaſion for its being Uſed there; For, if a *Receiver*, with the *Automaton* placed in it, be well exhauſted and freed from Air, by the help of the *Mercurial-Gage* at Land,(*as uſual*,) and a true Account be kept of the exact *Number* of *Strokes* of the Pump, that are neceſſary to Perform that Operation; Then undoubtedly that Receiver may at any Time after be exhauſted to the like Degree of *Vacuo* or *Emptineſs*, it was at that Time, with the ſame Number of *Strokes*; or at leaſt to ſuch a Degree as will be ſufficient for the preſent Purpoſe, without making Uſe of the Mercurial-Gage as before; Provided, that the Place or Hole, where the *Mercurial-Gage* was *Screw'd* to the Engine, have a *Screw* made to fit it ſo *exactly*, that no External *Air* can enter into the Receiver. And if the aforeſaid *Number* be Ingraven upon the Outſide of the Copper Caſe, (*in pretty large Figures,*) it will always be ready at Hand, to ſhew the Number of Strokes required to exhauſt the Receiver. Conſequently, there will be no need of a *Mercurial-Gage* at Sea. Nor indeed, any where Elſe,

to that *Receiver* with the *Movement* in it, after the firſt Time.

Now that *Screw*, in the Place of the *Mercurial-Gage*, will be a very convenient Thing to let the External *Air* into the Receiver, at ſuch Times as the Movement muſt be taken out of it, in Order to be wound Up: And in doing that, great Care muſt be taken to let the *External Air* into the Receiver gradually; and not ſuffer it to *Ruſh* in with *Violence*, which may be very eaſily done by Unſcrewing the aforeſaid *Screw* by a little at a Time, that ſo the Air may *Inſinuate* it ſelf by *Degrees*, between the *Joints* of the *Screws*, and ſo on, until it be quite Unſcrew'd, and the Hole be Open. A ſmall Share of Experience will render all this eaſie.

3. *Objection.* Altho' it be granted, that the Movement in its exhauſted Receiver, be freed from the *Influences* of the *Air*, with reſpect to its *Denſity*, *Moiſtneſs*, *Nitrous*, *Qualities*, *&c.* And alſo, that the Remaining *Æther* be according to Mr. *Boyle's* Experiments, neither *Hot* nor *Cold*, *&c.* Yet the Movement may ſtill be liable to the *Effects* of extream *Heat*, and *Cold*, in different *Climates*, and *Seaſons* of the *Year*, which may ſo Operate upon the *Oil*, *Springs* and *Wheels*, as to cauſe them to have an Irregular Motion.

Anſwer, I ſhall not here pretend to Argue, whether *Heat*, and *Cold* can have any *Effect* upon *Elementory* or *Material* Bodies, otherwiſe than as Conveyed to them by the *Medium* of *Air*; If it cannot, then the Objection is of no Force. But not to inſiſt upon that Point, becauſe the *Movement* may be defended from the *Effects* of extream *Heat*, or *Cold*: Thus, If the Ship be in any extream *Cold Climate*, (*or ſeaſon of the Year*,) let the Recipient, *&c.* be placed, (*or rather Hung up*,) in the Cook-Room, that ſo it may be kept Warm, or at leaſt freed from the Extremity of Cold. And on the contrary, If the Ship be in any Extremity of *Heat*, then let it be Placed or Hung in a Veſſel of Cold Water, in the Hold of the Ship, and by that Means it will be kept Cool enough, to preſerve it from the *Objected Effects*: And I am ſure that neither the Smoak in the Cook-Room,

Room, nor the Water in the Veſſel can do it any Prejudice.

Having now given the plaineſt *Deſcription* I can of the Movement, with the manner how it may be perfectly Secur'd or Defended from all the *various Influences* of the *Air*; and I hope, Freed from all Objections againſt its Uſe at Sea. Yet, before it can be truly Apply'd to the *Practical Solution* of the *Problem*, for Diſcovering the *Longitude* at *Sea*, it muſt be farther prepared to take a fair Leave of the Place or Port, from whence the Account or *Reckoning* of the *Ships Voyage* is deſigned to begin. And in Order to that, it will be neceſſary to ſhew the *Induſtrious Mariner*, that is to be its Governor, what I promiſed in Page 9, *viz.* how,

To draw a *True MERIDIAN-LINE.*

THERE are ſeveral Ways preſcribed by *Mathematical* Authors, (*eſpecially thoſe that Treat of Dialling*,) for drawing a Meridian-Line, upon an *Horizontal Plane*, but none that I ever yet met with, are either ſo eaſie to be Underſtood, or ſo exact for the preſent Purpoſe, as that I ſhall here Propoſe to be done by *Reflection*; the following Directions being carefully Obſerved.

Firſt, There muſt be Choſen a pretty Large *Room*, about *Nine* or *Ten Foot* High; Its Top or *Ceiling* ſhould be very Even and *Smooth*: And in all *North Latitudes*, it muſt have a Window ſo near the *South*, as that the *Sun* (*in the Summer Seaſon*,) may *Shine* into it, from about *Seven* or *Eight* a Clock in the *Morning*, till about *Five* in the *Evening*. But in all *South Latitudes*, the Window muſt Face the *North*, *&c.*

Having made Choice of ſuch a *Room*, the next thing will be to Provide a *Round Plano-Concave* Glaſs, about *Three Quarters* of an *Inch Diameter*; let its *Cavity*, (*or Hollow-Part*,) be in the *Middle* of the Glaſs, and Ground upon the *Segment* of a *Sphere*, whoſe *Axis* or *Diameter*, is about an Inch and Half, it muſt be ground as *Deep* as the Thickneſs of the Glaſs will permit, or until it be a Quarter of an Inch Broad, (*but not thorow*,) the plain Side

Side of the Glaſs muſt be ground very *True*, and well *Poliſhed*; And only the *Cavity*, or Hollow part in the other ſide, Ground true to its *Sphere*, and then well Poliſhed, that ſo it may be neatly Foil'd with *Quick-Silver*, in the ſame Manner as common *Looking-Glaſſes* are. When that's done, let it be Fixt into a Frame, (*about Two Inches Square*,) made of Copper, that ſo it may be ſecured from Breaking, and be more exactly placed in its true *Poſition*.

Note, *This Glaſs and its Frame*, &c. *may be had at any of the* Spectacle-Makers *in* London, (*eſpecially in* Ludgate-Street.)

The Glaſs being thus prepared, then in the *Baſes* or *Bottom* Board of the aforeſaid Window, about the *Middle* of the Opening of the *Caſement*, and pretty near the Outermoſt Edge of it, there muſt be made a *Mortiſs* or *Groov*, that will juſt Fit the Frame of the Glaſs to Lie in, there it muſt be Placed, and ſteadily Fixt, (*by Screws or Cement*, &c.) with the *Plain ſide* of the Glaſs uppermoſt, and exactly *Horizontal*, which may be eaſily done by the help of a *ſmall Level*, ſuch as Joyners or Carpenters make uſe of. And there ſhould be a Cover ſo Contrived as to keep the Glaſs from being *Damaged*, either by Weather or otherwiſe. Alſo, it will be very Convenient to have all the Window Darken'd, (*except the Caſement*,) when the Glaſs is made uſe of: That is, the *Darker* the *Room* is made at the *Time* of *Obſervation*, the better it will be for taking the *True Time*, when the *Sun* comes to the *Meridian*.

All things being thus prepared, then in a *Clear Sun* Shine Day, when the *Sun* is in the ſame *Hemiſphere* with the *Latitude*, uncover the Glaſs about *Eight*, or *Nine* a Clock in the Morning, and obſerve where the *Sun's Image* is *Reflected*, upon the *Ceiling* of the Room, *viz.* where there is a round *Bright-Spot*. In the very *Middle* of that *Spot* make a Point; and at the ſame *Moment* of *Time*, let a Second Perſon take the exact *Altitude* of the *Sun*, (*which may be very Accurately done, by the New Inſtrument recommended in Page* 6.) That is, the Sun's Altitude, and the Point made in the Bright Spot, muſt be

Perform'd

Perform'd both at one and the ſame Time, or as near it as 'tis poſſible, becauſe the Spot will Move pretty Faſt, and therefore one Perſon cannot well Perform both.

Again, in the *Afternoon* about the ſame diſtance of Time, from *Twelve* a *Clock*, as the firſt Obſervation was made at in the *Morning*; As, ſuppoſe the firſt Obſervation was made about *Eight*, then the Second muſt be made about *Four* in the Afternoon, &c. *(But beſure to be ſoon enough, leaſt the Time be paſt.)* Then obſerve the *Sun's Altitude*, if it be greater than it was in the Morning, ſtay a Little, and take it again, repeating the Obſervations until the *Sun's* Altitude be exactly the ſame with that taken in the Morning, and at the ſame *Moment* of *Time*, let another Perſon make a Point in the *Middle* of the New *Reflected Spot* upon the Ceiling, *(as in the Morning.)* I ſay, if thoſe Two Points be Joined by a *Right-Line*, and that Line be *Biſected* or Divided in the *Middle* by another *Right-Line*, at Right-Angles to it, the Biſecting-Line, being continued both Ways to the utmoſt Limits of the Ceiling, will be the *Meridian-Line* required. *(Which ſhould be drawn a Narrow Black-Line.)*

Now the Ground or Reaſon of *Projecting* this *Line* upon the Ceiling, by help of the Reflected Spots, will be very Evident to any Perſon, that only knows the firſt *Principles* of *Catoptricks*, *viz.* That the *Angles* of *Reflection*, are every where equal to the *Angles* of *Incidence*, Conſequently, when the *Sun* is upon any *Azimuth*, and its *Rays* are then *Reflected* from the Glaſs to the Ceiling, it will be eaſie to Conceive, that when the *Sun* comes to an *Azimuth* on the other ſide of the *Meridian*, and equally diſtant from it; *(which is known by the Sun's equal Altitudes,)* then its *Rays* being *Reflected* from the ſame Glaſs to the Ceiling, will alſo be equally diſtant from the *Meridian-Line* projected upon the Ceiling.

And therefore, as the *Center* of the *Sun* paſſes over the *Meridian* of the Place, *(from one Azimuth to the other,)* the *Center* of its *Reflected Image* will alſo paſs over the *Meridian-Line* drawn on the Ceiling. And

that;

that it may be exactly known, when the *Center* of the *Sun's* Reflected Image (*or Bright Spot*) is upon the *Meridian-Line*, it will be very neceſſary to draw a ſmall Black *Parallel Line* on each ſide of the Meridian-Line, at a Diſtance equal to the *Radius* of the *Spot*, for by that Means the *Eye* will be able to Judge when the *Center* of the *Spot* is upon the *Meridian-Line*, even to *Four* or *Five Seconds* of *Time*.

Thus have I ſhew'd the *Honeſt Mariner*, how he may draw this moſt uſeful Line, for adjuſting *Curious* Time Keepers; I call it the moſt uſeful, becauſe, by a *Meridian-Line* truly Drawn, all Movements, as *Pendulum Clocks* and *Watches*, &c. may be more Accurately adjuſted to the *True Time* of the Day, than by the Shadow of the *Gnomon* of the *Beſt*, and *Largeſt Dial* whatſoever.

And I eſteem it ſo uſeful for the preſent Purpoſe, as to Adviſe all *Maſters* of *Ships*, and their *Mates*, &c. to prepare ſuch a *Meridian-Line*, at every convenient Place or Port they come into; For this I can aſſure them, that if ever they intend to *Diſcover* the True *Difference* of *Longitude* between any *Two Meridians* or Places at Sea, they muſt be very Nice and Exact in Adjuſting their Movement to the *Meridian* of the Place from whence they take their Departure. *viz*, where the begin their Account or Reckoning of any *Voyage*.

But here I am aware there may be offered this following Objection.

Objection. That a *Meridian-Line* is not of ſuch general Uſe, as I here ſeem to Fix upon it, for it can be but of little Uſe in the *Torrid Zone*, *viz*. from the *Equator*, to about 24 *Degrees* on each Side of it.

Anſwer. 'Tis True that a *Meridian-Line* is the moſt Uſeful in the *Two Temperate Zones*, *viz*. betwixt the Twenty Forth, and Sixty Sixth *Degrees* either of *North* or *South* Latitudes. And it muſt alſo be Granted, that in the *Torrid Zone*, at ſometimes of the Year it cannot be of any Uſe at all; for when the *Sun* is in (*or near*) the *Zenith* of any Place, then its *Image* will *Reflect*, or Return directly back again into it *Self*; Conſequently there can be no Obſervation made by the *Meridian-Line*, at ſuch Times in thoſe Places.

But when either the *Latitude* is *North*, and the *Sun's Declination South*; or, the *Latitude* is *South*, and the Declination *North*; Then a Meridian-Line will be as Uſeful in the *Torrid-Zone*, as in the *Temperate-Zones*. And when the *Sun* is in, or, near the *Zenith* of any Place, then its *Altitude* may be taken to the beſt Advantage, for there every *Fifteen Degrees* of *Altitude* makes but one *Hour*; ſo that if the *Sun's* Meridian Altitude can be taken but to *Four Minutes* of a Degree, *(which may be done to leſs,)* the Time is thereby Determin'd to *Sixteen Seconds*, &c. Now here it will be very neceſſary to give the honeſt *Seamen*;

An *Account* of the *Two Sorts* of *Time*.

Viz. The *APPARENT Time*, and the *EQUAL* or *Mean Time*; both which he ought to underſtand very well.

THE *APPARENT* Time is that which is Traced out, and becomes known, by the *Shadow* of the *Gnomon (or Stile,)* upon the *Hour-Lines* of a True *Sun*-Dial, or is found by the *Sun's Altitude*, &c. In ſhort, that Time which is any way ſhew'd by the *Sun*, is called *Apparent Time*; And its generally Accounted amongſt moſt People, *(eſpecially the Vulgar ſort)* to be the *True* and only *Time*. For, ſay they, it is Plain to us, that the *Sun* keeps a conſtant *Motion*, and ſhews upon the Dial, that every Day between *Noon* and *Noon*, is juſt Twenty Four Hours Long, at all times of the Year alike. But this is a great Miſtake; For it is well known to all thoſe that have the leaſt *Smattering* of *Aſtronomy*; That the *Sun Moves Faſter* in one part of the Year, than it doth in another, Conſequently the Time ſhewed on the *Dial*, or any other way by the *Sun*, muſt needs be *Unequal*; Aud therefore the *Ingenious Mariner*, that intends to Diſcover the *Longitude* at *Sea*, ſhould be thorowly acquainted with the Equal Time.

The *EQUAL Time*, being that which is *Meaſured* by the Regular Motion of the *Equinoctial*, *(as I've ſaid before*

before, Page 6,) which makes, (*or Compleats*) one intire *Revolution*, from any one *Meridian* (*or Point in the Heavens*,) to the very ſame *Meridian* (*or Point*) again, every Day in the Year exactly in Twenty Four Hours. Whereas, the *Apparent* Time Meaſured by the *Motion* of the *Sun*, is ſome Days in the Year about *Fifteen Minutes Faſter*, and other Days about *Fifteen Minutes Slower* than the Equal or True Time, and therefore the Equal (*or Equinoctial*) Day is very often called the *Mean* Day.

And this *Inequality* or Difference, between the *Equal* or *Mean* Day, and the *Apparent*, ariſes from a Two-fold cauſe; As is moſt *Ingeniouſly Demonſtrated* by the *Learned Mathematician*, and *Reverend* Divine Mr. *John Flamſtead*, *Aſtronomer Royal* at *Greenwich*, near *London*. And upon his *Hypotheſes*, I have Calculated the *Annexed Tables* for Equating the Apparent Time, to the *Equal* or True Time, every Day in the Year.

Note, The Table is Calculated (*De nova*) for the Year 1722, and will ſerve very well for Twenty or Thirty Years to come, without any ſenſible Error. And the only Difference between it, and thoſe Uſually called *Tables* of the *Equation* of *Natural Days*, is this; inſtead of *Watch* (*or Clock*) too *Faſt*, or Watch too *Slow*; I have it thus; *Add* to the *Apparent Time*, or *Subſtract* from the Apparent Time, *viz.* the *Number* of *Minutes* and *Seconds* that are found in the *Column* under the Month, and juſt againſt the propoſed Day of that Month, muſt be *Added* to, or *Subſtracted* from the Apparent Time, ſhew'd by the *Sun* that Day, and the *Sum*, or *Difference* will be the *Equal* or *Mean* Time required.

An Example of Adjuſting the *Automaton* to keep equal Time, will ſhew the Uſe both of the Tables, and of the *Meridian-Line*, (as promiſed Page 9.)

Example.

SUppoſe the Firſt of *January* being a *Clear Day*, I would *Adjuſt* the *Automaton*, or any other Movement, as *Watch*. *&c.* to keep *Equal Time*.

I look into the Equation Table, (*before Noon*,) and againſt the propoſed Day, find, that 9 *Minutes*, 2 *Seconds* are to be *Added* to the *Apparent Time*; ſo that when it is juſt 12 a Clock by the *Sun*, it will be 9 *Min.* 2 *Seconds* paſt 12, according to the *Equal Time*. Therefore I muſt carefully Obſerve by the *Meridian-Line*, (*as before directed*,) when the Center of the *Sun* is exactly upon the *Meridian*, and immediately ſet the *Indexes* of the *Movement* to 9 *Minutes* and 2 *Seconds* paſt 12, which is the true Equal Time for that Day. Then I Place the *Automaton* in its *Recipient*, and *exhauſt* the *Air*, *&c.* and let it go on for a Fortnight, or Month; as ſuppoſe, until the 30th of *January*, which proving a Clear Day, then to Try whether the *Automaton* hath kept Equal Time or not, I look into the *Equation Table*, and find that 14 *Minutes* 50 *Seconds*, are to be *Added* to the *Apparent Time* that Day; And (*at Noon*,) I obſerve by the *Meridian-Line* (*as before*,) when the *Sun* is exactly upon the *Meridian*, and if the *Indexes* of the *Movement* be then juſt 14 *Minutes* 50 *Seconds* paſt 12 a Clock, it has kept Equal Time that Month; if not, it muſt be taken out of the *Recipient*, and be Rectified thus; If it has gone too *Faſt*, the Two *Spiral-Springs* that are fixt to the *Verge* of the *Ballance*, (ſee Page 9,) muſt be both equally *Lengthened* a little; But if it has gone too *Slow*, then they muſt both be equally *Shortned* a little. Now the way of doing that, will be much better Underſtood, even in a Minutes Time, when ſhew'd by the *Maker* of the *Movement*, than it can poſſibly be here by Writing. Not but that the Buſineſs of Adjuſting the *Movement* to keep equal Time in its *Recipient*, ought to be perfectly Compleated by the Artiſt that makes it, before he Delivers it for Uſe. Yet it will be very Convenient, the Ingenious Mariner ſhould know how to do it upon Occaſion.

In ſhort, the *Movement* muſt be ſo often Try'd in this Manner, and *Rectified* according as it requires, (*either by its Maker, or by its Maſter*,) until it will keep *equal Time* in the Place where it is ſo Adjuſted. Or otherwiſe, it will not be duly prepar'd to Anſwer the Deſign

of

of *Diſcovering* the *Longitude* at *Sea*, to that exactneſs as is required.

For, let the *Moving* parts of any *Clock* or *Watch*, *&c.* even of *Oſcillating Pendulums* (or thoſe call'd the *Royal Pendulums*,) be never ſo well made, and put together by the greateſt *Skill* of the moſt *Ingenious* and Experienced *Artiſt*; and let it be then Adjuſted by any other Way or Contrivance whatſoever, with the utmoſt care of *Man*; yet its Motion cannot be made to Correſpond, or keep Time with the *Sun*. (*Vide the Reaſons mention'd Page* 19,) for indeed the Perfection of all *Clocks*, and *Watches*, *&c.* is to make them go exactly Equal: That is, to *Meaſure* out 24 *Hours*, (or a Natural Day,) at any one Time of the Year, juſt as long as 24 Hours at another Time of the Year, and to Perform that Equal Motion conſtantly all the Year Round. So that unleſs the *Apparent Time* be truly *Æquated* to the Equal, or (*which is indeed Equivalent*,) the *Equal Time* ſhew'd by a true *Movement*, be *Equated* to the *Apparent Time*; I humbly Conceive it Impoſſible to Diſcover the true *Difference* of *Longitude* between any Two Meridians, that lye Remote one from the other. And if ſo, I believe every Body will agree with me, that its moſt proper to *Equate* the *Apparent Time*, to the *Equal Time*, which is Meaſured by the *Equinoctial*.

The next thing in Courſe will be, to ſhew,

How to find the *APPARENT TIME* at *Sea*.

1. IF it could be truly known at *Sea*, when the *Sun* (or any *Fixed Star*,) were exactly upon (*or rather under*) the *Meridian* of the Place, where the Ship is, the thing were then done; but altho' that's always preſum'd to be known, when there is an *Obſervation* made of the *Sun's Meridian Altitude*, for taking the *Latitude* at *Sea*, and near the Equinoctial, it may do well enough, yet it muſt not be depended upon as a general Method of knowing the exact *Time* in all *Latitudes*. For I do aſſure you, that it's a very difficult thing to know when the *Sun*, (or *any Fixt Star*,) comes exactly to the *Meridian*,

dian, even at *Land*, and much more Difficult, if not Impoſſible to be known at *Sea*.

2. But a more certain way of finding the *Hour* of the *Day* at *Sea*, is, to Obſerve the *Sun's* true Altitude about Eight a Clock in the *Morning*, or about Four in the *Evening*, becauſe about thoſe *Times* the Sun's *Altitude* changes more ſenſibly than it doth either before, or after. Then by having the *Latitude* of the Ship, the *Declination* of the *Sun*, and its Altitnde given, the Hour and Minute of the Day may be truly *Calculated*; as is ſhew'd in moſt Books of *Navigation*.

3. Or, the *Time* of the *Night* may be exactly found, by taking the True *Altitude* of any *Fixed Star*, whoſe *Right Aſcention*, and *Declination* is known, and then proceeding to a Trigonometrical Calculation, as before with the *Sun*, &c.

But, becauſe thoſe Calculations muſt be perform'd by the *Solution* of an *Oblique Spherical Triangle*, wherein the *Three-Sides* are given to find an *Angle*, which requires a double Operation; they may therefore be thought too Difficult, and *Operous* for common Practice, I ſhall for that reaſon Omit giving any Examples thereof, and leave them to the *Ingenious Mariner's* Conſideration, to make Uſe of them when he thinks moſt Convenient, and proceed to ſome other Methods more eaſie in Practice.

4. The *Apparent Time* at Sea, may be found pretty near the Truth, by a Method which the *Great* Mr. *Huygens* preſcrib'd for the Uſe of his Watches. (Vide *Philo. Trans. Abridg'd, Vol.* I. *Page* 641.) which I ſhall make Bold to Inſert here in his own Words, 'At the *Riſing* and *Setting* of the *Sun*, when it is 'half above the Horizon, Mark the Time of the 'Day, which the *Watches* then ſhew; and though ye 'have in the mean time Sailed on, it is not conſiderable. 'Then Reckon by the *Watches*, what Time is Elapſed 'between them, and *Add* the half thereof, to the Time 'of the *Riſing*, and you ſhall have the Time by the '*Watches*, when the *Sun* was at *South*; to which is to 'be *Added*, the Equation of the preſent Day by the

'Table

' Table: (And then he proceeds to an Example, which I ſhall here Omit.)

' 'Tis Manifeſt (*ſaith he,*) that by this way you find ' Preciſely enough the *Longitude* of the Place, where ' you were at *Noon*, or the Time of the *Sun's* being in ' the South, which although it differs from the *Longi-* ' *tude* of the Place, where you are when you Obſerve ' the *Setting* of the *Sun*, yet you may Eſtimate near ' enough, how much you have Advanced, or chang'd ' the *Longitude* in theſe few Hours, by the *Log-Line*, ' *&c.* or (which is the ſurer way,) by the *Degrees* paſ- ' ſed in 24 Hours by a former Days Obſervation.

, 5. You may alſo, inſtead of Obſerving the *Sun's* ' *Riſing* and *Setting*, obſerve the *Setting* firſt, and then ' the next Morning the *Riſing*, Marking both Times, ' *&c.* and find thence, after the ſame Manner as before ' the *Longitude* of the Place, where the Ship was at ' Midnight.

' Or inſtead of the *Riſing* and *Setting* of the *Sun*, the ' ſame Thing may be Perform'd by Obſerving two ' equal *Altitudes* of the *Sun*, one before, and the other ' after *Noon*; *&c.* or by taking two equal *Altitudes* of ' ſome known Star, that *Riſeth High* above the Horizon, ' for by its *Right Aſcention*, and the *Right Aſcention* of ' the *Sun*, you may eaſily Calculate what time the Star ' was in the *Meridian*, *&c.*

Undoubtedly any of theſe Ways may be very eaſily Perform'd in Practice. But it muſt be Conſidered, that they all require a neceſſity of having *Two Obſervations* to be made in one and the ſame Day, *(or Night,)* altho' the Latitude cannot be found by either of them; And when *Two* ſuch Obſervations can be made, even then Mr. *Haygens* does not ſay the Longitude can be Preciſely found, but only near enough, altho' it be *Corrected* by Eſtimating how much the *Longitude* is chang'd between thoſe two *Obſervations*. (Beſides the uncertainty of Gueſſing when the *Sun* is juſt half above the *Horizon.*) However, its not to be doubted, but theſe *Methods* were thought near enough, when that *Ingenious Perſon* preſcrib'd them; But the ſtrict Limits now injoined by the

the late *Act* of *Parliament*, require it to be more exactly Diſcovered; which I hope will be Perform'd by the following Method.

6. The *Time* where the Ship is at *Sea*, may be very eaſily and exactly found by an *Obſervation*, made either of the *Sun's Riſing*, or *Setting*, the Obſervation being duly *Corrected* by the *Sun's Horizontal Parallax*, and *Refraction*; becauſe the *Parallax* makes it appear a *Little Lower* than the Horizon, and the *Refraction* makes it appear ſomewhat *Higher* than it really is.

Now the *Sun's Horizontal Refraction*, is found by the Accurate Obſervations of the (*aforeſaid*) *Ingenious* Mr. *Flamſtead* the *Royal Aſtronomer*, to be about 33 *Minutes* of a *Degree*. And its Horizontal *Parallax*, is ſuppoſed to be about 32 *Seconds* of a *Degree*, which being *Subſtracted* from the *Refraction*, leaves 32 *Minutes* and 28 *Seconds* for the true Correction required.

But, becauſe the *Sun's* Apparent Diameter (*at its mean Diſtance from the Earth*,) is Obſerved to be about 32 *Minutes* and 15 *Seconds* of a *Degree*, which is very near Equal to the aboveſaid Correction found by its *Parallax* and *Refraction*; It therefore follows, that a *True*, and *General Rule* may be propoſed for Correcting the *Time* of the *Sun's Riſing*, or *Setting*, in all *Latitudes* and Seaſons of the Year.

General Rule. If the trne Time, the whole Body of the *Sun*, is either Riſing, or Setting, be *Nicely Obſerved*, by the *Indexes* of the *Automaton*; And that Time be Subſtracted from the Time of its *Riſing*, found by *Calculation*, the Remainder will be the Time when the *Center* of the *Sun* did appear to be in the *Horizon*. Or if it be Added to the Time of the *Sun's* Setting, the *Sum* will ſhew the Time when its *Center* did then Appear to be in the Horizon, and this Rule holds good, notwithſtanding the Difference of Time which the *Sun* takes in its *Riſing* or *Setting*, according as the Angle of its Diurnal Motion is Acute, or Obtuſe with the Horizon, which continually *varies*, both with the *Latitude*, and Seaſons of the *Year*.

Now

Now if the Latitude of the Place, and the *Sun's* Declination are both given, the True Time either of the *Sun's Riſing*, or *Setting* may be very eaſily Calculated by this *General THEOREM.*

As the Radius : Is to the Tangent of the Latitude :. So is the Tangent of the Sun's Declination : To the Sine of an Arch of the Equinoctial, called the Sun's Aſcentional Difference.

Then that *Aſcentional Difference* being Converted into Time, (*by Allowing* 15 *Degrees to an Hour, &c.*) will ſhew how Long the *Sun Riſes*, or *Sets*, either before or after *Six* a Clock; which Admits of two *Caſes.*

Caſe 1. If the *Latitude* of the Place, and the *Sun's Declination* are both on the ſame ſide of the *Equinoctial*; (viz. *both* North, *or both* South,) then Subſtract the *Aſcentional Difference* from *Six Hours*, and the Remainder will ſhew the Time of the *Sun's Riſing*; And being Added to *Six Hours*, the Sum will ſhew the Time of its Setting.

Caſe 2. But if the *Latitude*, and *Declination* are of contrary Names; (viz. *if one be* North, *and the other* South,) then the *Aſcentional Difference* muſt be Added to *Six Hours*, and the Sum will ſhew the Time of the *Sun's Riſing* after Six; And if it be Subſtracted from *Six Hours*, the Remanider will ſhew the Time of its *Setting* before *Six*, in the Evening.

I ſhall now Apply what has hetherto been Said concerning the *Solution* of the following *Problem*, to an Example or Two, which will (*I hope*) make all Plain, and Eaſie to be Underſtood by the *Honeſt Marriner.*

PROBLEM.

To *Diſcover* the *Longitude* at *Sea.*

THAT is, It is Required to *Diſcover* the exact *Number* of *Degrees* and *Minutes*, which are contain'd in that *Arch* of the *Equinoctial*, which *Meaſures* the *Horary Diſtance* (*either* Eaſt, *or* Weſt) between the *Meridian* of the Place from whence a Ship begins her Voyage, and the *Meridian* of any Place where ſhe is afterwards, either at *Sea*, or in any *Port.*

SOLUTION.

TO *Reſolve* this uſeful *Problem*, the *Automaton* muſt be very carefully *Adjuſted* to the *equal Time*, under the *Meridian* of the Place where the Ship begins the *Voyage*; that being the Place where the Account of *Longitude* do's then begin; And whereſoever the Ship is at any Time afterwards, the *Automaton* is then truly prepar'd to ſhew what a Clock it is according to the *equal Time*, at that Place where it was ſo *Adjuſted*. Conſequently the equal Time being truly found at the Place where the Ship is; the Difference between that Time, and the Time ſhew'd by the *Movement*, will be the *True Meaſure* of the contained *Arch* of the *Equinoctial* in *Time*. Then if the *Time* ſo found, be Converted into *Degrees* and *Minutes* of the Equinoctial, by Allowing 4 Minutes of *Time* to a *Degree*, and 15 *Degrees* to an Hour; which may be very eaſily and exactly done, (*or the contrary*) by the help of a ſmall *Table*, I have Annexed at the end of this Tract, for that purpoſe; whoſe Title ſhews its Uſe by *Inſpection* only. Thoſe Degrees and Minutes will Diſcover (*or ſhew*) the Difference of *Longtiude* required by the *Problem*.

Example 1:

SUppoſe a Ship begins a *Voyage* the 25th of *March*, 1715. from *Plymouth*, *Latitude* 50 *Degrees* 36 *Minutes* North, and is deſign'd for *Port-Royal* in the Iſland of *Jamaica*, whoſe Latitude is 17 *Degrees*, 40 *Minutes* North: And its Difference of *Longitude* from *Plymouth*, is about 72 *Degrees Weſtward*.

The Ship being out at Sea, plys upon a S W by W courſe, until the 10th of *April*, which proving a clear *Morning*, I obſerve the *Sun's Riſing*, and juſt as the upper *Limb* or *Edge* of the *Sun* begins to Appear in the Horizon, the *Indexes* of the *Automaton* ſhew the Time to be exactly 31 *Minutes*, and 26 *Seconds* paſt 5 a Clock. And its *lower Limb* or *Edge*, leaves the Horizon at 35 *Minutes*, and 38 *Seconds* paſt 5.

From

From 5 h. 35 *M.* 38 *S.* the *Time* the *Sun* left the Horizon.
Subtr. 5 h. 31 *M.* 26 *S.* the *Time* of its firſt Appearing.
Rems. 0 h. 4 *M.* 12 *S.* the *Time* it was in *Riſing*.

Conſequently if 0 h. 2 *Min.* 6 *Sec.* half the *Time* the *Sun* was *Riſing*, be Added to the *Time* of its firſt Appearing, the *Sum* will be 5 h. 33 *Min.* 32 *Sec.* for the *Time* by the *Automaton*, when the *Center* of the *Sun* appeared to be in the Horizon.

N. B. *The Time while the* Sun *was* Riſing, *and the Time when its* Center *appeared to be in the* Horizon, *muſt both be carefully ſet down and Reſerved for the work, after the* Latitude *is found by Obſervation at* Noon.

Then, the Day continuing Clear, I obſerve the *Sun's Meridian Altitude*, and find the Latitude of the Place to be 45 *Degrees*, 54 *Minutes* North; the *Sun's Declination* being then 11 *Degrees* 46 *Minutes* North. Now by theſe Two, *viz.* the Latitude, and Declination, I might proceed (*as uſual*) to find the Time of the *Sun's Riſing*. But before that can be done, to Anſwer the deſign of *Diſcovering* the true *Difference* of *Longilude*, between *Plymouth* and the Place where the Ship is; we muſt conſider, that both the *Latitude* and *Declination*, (*as well as the Longitude*,) are Altered between the Time of the *Sun's Riſing*, and its coming to the *Meridian* when the Latitude was found, and therefore both of them ought to be Corrected, before the Time of the *Sun's Riſing* can be truly Calculated.

And firſt for the *Sun's Declination*, which may be nearly Corrected by taking a fourth Part of its Daily Difference, and then Adding it To, or Subſtracting it From the *Sun's Declination* at *Noon*, according as the Declination *Increaſes* or *Decreaſes*; Thus in the preſent Example, the Daily Difference of Declination is 20 *Minutes Increaſing*, the fourth Part of that, is 5 *Minutes*, which being duly ordered the Declinations for that Day will be;

Thus { At *Six* a Clock in the *Morn.* it was 11 *Deg.* 41 *Min.*
At *Noon* it is - - - - - - - - - 11 *Deg.* 46 *Min*
At *Six* in the *Even.* it would be 11 *Deg.* 51 *Min.*

Next

Next, It will be very eaſie to know how much the Ships Latitude is Altered in the Time, between the *Sun's Riſing*, and *Noon*, (*viz.* in 6 or 7 *Hours &c.*) by that which Seamen call the *Dead Reckoning*, kept by the Courſe and Diſtance, as in the Common Practice by plain *Sailing*. Then if that Alteration be *Added to*, or *Subſtracted from* the Latitude, found by Obſervation at Noon, according as the Courſe the Ship Sails upon requires, the *Sum*, or *Difference* will ſhew the Latitude at *Sun Riſing*.

As for Inſtance in the preſent Example, admit, I Compute the Ships Latitude to Alter 7 *Minutes Decreaſing* in *Six hours*, the Latitude Corrected will ſtand,

Thus { At *Six* in the *Morning* it was 46 *Deg.* 01 *Min.*
At *Noon* it is by *Obſervation* 45 *Deg.* 54 *Min.*
At *Six* in the *Even.* it will be 45 *Deg.* 47 *Min.*

Being thus prepared with the Morning *Declination*, and *Latitude*; I may now proceed with them, to find the true Time of the *Sun's Riſing*, by the general Theorem,

Thus { *Radius* - - - - - - - - - - - - - - - - 10. 0000000
Latitude 46 *Deg.* 01 *Min.* its *t.* 10. 0154156
Declination 11 *Deg.* 41 *Min.* its *t.* 9. 3155226

The *Aſcentio. Diff.* is 12 *Deg.* 22 *Min.* its S. 9. 3309382

Which being Converted into Time, (*by the Table, &c.*) gives 49 *Min.* 28 *Sec.* the Time which the *Sun Riſes* before *Six* a Clock. Therefore from 6 h. 00 *Min.* 00 *Sec.*
I Subſtract the *Aſcentional Differ.* 0 h. 49 *Min.* 28 *Sec.*
There remains the true Time 5 h. 10 *Min.* 32 *Sec.*
of the *Sun's Riſing* in the Horizon.

From which Subſtract, (*per General-Rule*) the Time the *Sun* was in *Riſing*, *viz.* 0 h. 04 *Min.* 12 *Sec.*
The remainder ſhews the Time 5 h. 06 *Min.* 20 *Sec.*

When the *Center* of the *Sun appeared* by Obſervation in the Horizon. Which being *Equated* to the *equal Time*, by the *Equation Table* for that Day is, 5 h. 04 *Min.* 50 *Sec.*

From hence I have found the equal Time, when the *Center* of the *Sun* did appear by Obſervation, to be in the Horizon of the Place, where the Ship was in the Morning; and the *Indexes* of the *Automaton* ſhewed me, that the equal Time was then at *Plymouth*, juſt

5 h.

5 h. 33 *M.* 32 *Sec.* Consequently their Difference will be the True *Horary* distance upon the Equinoctial between *Plymouth*, and the Place where the Ship was at the *Sun's Rising*.

Viz. from 5 h. 33 *M.* 32 *S.* the equal Time at *Plymouth.*
I substract 5 h. 04 *M.* 50 *S.* the equal time at the Ship.
Remains 0 h. 28 *M.* 42 *S.* their *Horary* Distance on the Equinoctial; which being turn'd into *Degrees*, &c. (*per Table*,) gives 7 *Degrees*, 10 *Minutes*, and 30 *Seconds* of a *Degree*, for the Difference of Longitude required by the *Problem.*

Now altho' it may be known whether the Ship hath alter'd her Longitude *Eastward*, or *Westward*, by the Course she Sailed upon; yet it will be very easie to Determine that, by considering the *Description* given of *Longitude*, in page *6.* From whence it plainly appears, that if the equal Time found by Observation at the Ship, be *Less* than that shew'd by the *Automaton*, (*viz. Slower, as in our present Example*,) then the Ship has Altered her Longitude *Westerly*, from the Meridian of the Place, where the Account of *Longitude* began: But if it be greater (*viz Faster*,) than that shew'd by the *Automaton*, the Ship will then be under a more *Easterly* Meridian, consequently when both those Times prove to be *exactly* the *same*, the Ship will be still under the same Meridian of the Place from whence she came: Whence it follows, that the Ship is now 7 *Degrees*, 10 *Minutes*, 30 *Seconds*, *West* of *Plymouth.*

Example 2.

THE Ship proceeding Forward in her Voyage, and the Third of *May* following, being pretty clear at Noon, I take an *Observation* for the *Latitude*, and find it 33 *Deg.* 42 *Min.* North, the *Sun's Declination* being then 18 *Deg.* 34 *Min.* North *Increasing*, and its daily Difference 14 *Min.* Then in order to Observe the *Sun's Setting*, &c. I Compute the Ships Run, to Decrease the Latitude about 8 *Min.* in 7 *Hours*, and the *Sun's* Declination to *Increase* 4 Min. in that space of Time, so that the Latitude, and Declination corrected will stand Thus

The

The *Latitude* at *Noon* by Obſervation is 33 *Deg.* 42 *Mi.*
The *Latitude* at 7 in the *Evening*, is 33 *Deg.* 34 *Mi.*
The *Sun's Declination* at *Noon*, is 18 *Deg.* 34 *Mi.*
The *Declination* at 7 in the *Evening*, is 18 *Deg.* 38 *Mi.*

Then the Evening proving Clear, I Obſerve that the Lower *Limb* or *Edge* of the *Sun* juſt Touch'd the Horizon, when the *Indexes* of the *Automaton* Point at 32 *Min.* and 30 *Sec.* paſt 8 a *Clock.* And its upper *Limb* or *Edge*, Juſt diſappears under the Horizon

At - - - - - - - - - - - - - - - - 8 h. 36 *Min.* 38 *Sec.*
Subſtract its beginning to *Set*, *viz.* 8 h. 32 *Min.* 30 *Sec.*
Remains the Time it was *Setting* 0 h. 4 *Min.* 8 *Sec.*
The *Half* thereof 0 h. 2 *M.* 4 *S.* } being *Added* to the *Time* when the *Sun* began to *Set*, will be } 8 h. 34 *Min.* 34 *Sec.*

The Time by the *Automaton*, when the *Center* of the *Sun* appeared to paſs the Horizon.

Then for the true Time of the *Sun's* Setting, it will be *per General Theorem.*

Thus { *Radius* - - - - - - - - - - - - - - - - 10. 0000000
Evening Lati. 33 *deg.* 34. *min.* its t. 9. 8218803
Declination 18 *deg.* 38. *min.* its t. 9. 5278682

The *Aſcen. Dif.* is 12 *deg.* 56 *min.* its Sine. 9. 3497485

Which Turn'd into Time is, 51 *M.* and 44 *S.* So long the *Sun* ſet paſt 6 a Clock, *viz.* at 6 h. 51 *Min.* 44 *Sec.*
Add the Time the *Sun* was in Sett. 0 h. 4 *Min.* 8 *Sec.*
(*per Gen. Rule*,) And the Sum is, 6 h. 55 *Min.* 52 *Sec.*

The Time when the *Sun's Center* appear'd to be in the Horizon; Which being *Equated* to the equal Time, by the *Equation Table* for that Day, is 6 h. 51 *Min.* 40 *Sec.*

From hence I have Obtain'd the equal Time, when the *Sun's Center* did appear by Obſervation to be in the Horizon of the Place where the Ship is;

And the *Indexes* of the *Automaton* ſhew'd me that the equal Time was then at *Plymouth*, 8 h. 34 *Min.* 34 *Sec.*
Subſtract the Time at the Ship, *viz.* 6 h. 51 *Min.* 40 *Sec.*
And their Difference will be 1 h. 42 *Min.* 54 *Sec.*

The *Horary* Diſtance on the *Equinoctial*, which being turn'd into *Degrees*, &c. (*per Table*,) will give

25

25 *Deg.* 43 *M.* 30 *S.* for the true Difference of Longitude between *Plymouth*, and the Place where the Ship is, it being ſo much *Weſt* of *Plymouth*.

Now theſe Two *Examples* are (*I preſume*,) ſufficient to ſhew how the *Difference* of *Longitude* may be found, either by a *Morning*, or an *Evening* Obſervation, great Care being taken to make a true and exact *Computation* of Time, even to one Second.

And in order to prevent the *Loſs* of Time any Way, I think it very Convenient to Add.

N. B. In the Uſe of any *Clock*, or *Watch*, *&c.* it may be Obſerv'd, *(and is but reaſonable to expect.)* that when the *Force* or *Strength* of the *Main-Spring*, (*which is the Cauſe of its Motion*,) is almoſt ſpent; *viz.* when the *Movement* is near being Down, then its Motion will Abate or go *Slower*. And therefore to prevent any *Defficiency* in the preſent deſign that way; it will be very Neceſſary to have *Two Automatons* in a Ship, with a *Recipient* to each of them, (*eſpecially in long Voyages*,) One of them to be kept conſtantly going, and the other to be kept in its *Recipient* at *Reſt*. And when the Moving *Automaton* is almoſt down; (*as ſuppoſe it wants only a Day or Two of being ſo*,) then muſt the *Automaton* at *Reſt*, be taken out of its *Recipient* to be wound up, and ſet exactly to the Time ſhew'd by that which is in *Motion*; which being done, put it into its *Receiver* again, *Exhauſting* the *Air*, *&c.* as at Firſt; and let the other go down, and continue ſo in its *Recipient* at Reſt, *&c.*

Thus have I ſhew'd all that I can Conceive, neceſſary to Accompliſh the Diſcovery of the Difference of Longitude, between any Two Places at *Sea*.

And when once all *Geographers*, ſhall agree and *Pitch* upon a *proper* Place, (*as ſuppoſe*, *Pico Tenariff*, *&c.*) for the *Prime* or *Firſt Meridian*, from whence the *Degrees* of *Longitude* muſt be Accounted; Then may the *Longgitude* of any Place on either Side of that *Meridian*, be as certainly known, as now the Degrees of Latitude are on each Side of the Equinoctial, which is all that's wanting to Compleat both Navigation, and Geography.

However

However, whether that be ever done or not, it is very ſufficient in the buſineſs of Voyaging (*or Sailing,*) to know the *Difference* of *Longitude* only, (as above) for by that and the true Difference of *Latitude*, every Ordinary Mariner may be Able to Correct his Dead Reckoning, and keep a true Account of any *Voyage*; without being *Puzled* with ſuch doubtful Allowances, as are required to be made, for *Storms*, ſetting of *Currents*, with thoſe of *Tides*, the Ships *Lee-Way*, the *Variation* of the *Needle* or *Compaſs*, and the uncertainty of the Diſtance Sail'd by the *Log-Line*, *&c.* which are at preſent the unavoidable Difficulties that all Ingenious Mariners Labour under, in computing their *Traverſes*.

And in order to take off thoſe *Difficulties*, I did compoſe, A New Practical *Method* of *Reſolving* all the uſeful *Problems* in Navigation to great Exactneſs; Independent either upon that called *Mercators Sailing*, or the *Arch* of a *Great-Circle*. Wherein was Deſign'd this Method of Diſcovering the Longitude, with the *Deſcription*, and Uſe of the New *Inſtrument* for finding the true Latitude, mention'd in page 6. All which, if Sickneſs had not prevented me, I thought to have *Publiſhed* about *Seven Years* ago; by this Title, The *ART* of *NAVIGATION Improv'd*; it was then ſo ready for the Preſs, that Mr. *R. Mount* Bookſeller, on *Tower-Hill*, and Mr. *W. Taylor* Bookſeller, at the Ship in *Pater-Noſter-Row*, were both with me, to have Purchaſed the Copy, before I left *London*, (*which was in July*, 1710.) but I was not then willing to part with it ſo, nor able to Attend the Printing of it my Self, and therefore it was laid by.

But the Honourable Commiſſioners, to whom I have moſt humbly Dedicated this Tract; being Impower'd to Receive Propoſals for Improving the Art *of* Navigation, *and to Encourage the ſame; I do alſo with humble Submiſſion propoſe to their Honours, the above-mention'd Treatiſe, as a more Conciſe and uſeful Method of Sailing than yet Publiſh'd: which if their Honours Pleaſe to lay their Commands upon me, ſhall be Printed*; (unleſs Death, or extream Illneſs, Prevent it.) *And then I think to Cloſe up all my Labours with*

FINIS.

A New Correct Table for Equating of Time.

Days.	January.		February.		March.		April.	
	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.
1	9	02	14	50	10	07	0	44
2	9	26	14	49	9	49	0	28
3	9	49	14	47	9	31	0	12
4	10	11	14	43	9	13	0	04
5	10	31	14	38	8	55	0	20
6	10	51	14	33	8	37	0	34
7	11	10	14	28	8	19	0	48
8	11	29	14	22	8	01	1	02
9	11	47	14	16	7	43	1	16
10	12	03	14	09	7	25	1	30
11	12	18	14	01	7	06	1	43
12	12	33	13	52	6	47	1	55
13	12	47	13	43	6	28	2	07
14	13	01	13	33	6	09	2	18
15	13	14	13	22	5	50	2	29
16	13	27	13	10	5	31	2	39
17	13	39	12	58	5	12	2	49
18	13	50	12	46	4	53	2	58
19	14	00	12	34	4	35	3	07
20	14	08	12	22	4	17	3	15
21	14	15	12	09	3	58	3	23
22	14	22	11	56	3	39	3	31
23	14	28	11	42	3	20	3	38
24	14	34	11	27	3	01	3	44
25	14	39	11	11	2	43	3	50
26	14	43	10	56	2	25	3	55
27	14	46	10	40	2	07	3	59
28	14	48	10	24	1	50	4	03
29	14	49			1	33	4	06
30	14	50			1	16	4	09
31	14	51			1	00		

Add Time. Apparent Time to the Add Time. Apparent Time to the Add Time. Apparent Time from the Subtract Time.

* Add

A New Correct Table for Equating of Time.

Days.	May.		June.		July.		August.	
	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.
1	4	11	1	08	4	52	4	35
2	4	11	0	48	5	00	4	25
3	4	12	0	36	5	08	4	15
4	4	12	0	23	5	14	4	04
5	4	13	0	10	5	19	3	52
6	4	14	0	03	5	24	3	40
7	4	13	0	16	5	29	3	27
8	4	11	0	29	5	34	3	14
9	4	08	0	42	5	38	3	01
10	4	04	0	55	5	42	2	47
11	4	00	1	08	5	46	2	33
12	3	56	1	21	5	49	2	18
13	3	51	1	34	5	51	2	03
14	3	46	1	37	5	52	1	47
15	3	41	1	59	5	53	1	31
16	3	35	2	12	5	53	1	15
17	3	28	2	24	5	52	0	58
18	3	21	2	36	5	51	0	41
19	3	13	2	48	5	49	0	24
20	3	05	3	00	5	47	0	06
21	2	56	3	12	5	44	0	13
22	2	47	3	24	5	41	0	32
23	2	38	3	35	5	37	0	51
24	2	29	3	46	5	33	1	10
25	2	19	3	56	5	28	1	29
26	2	08	4	06	5	22	1	49
27	1	57	4	16	5	17	2	09
28	1	46	4	25	5	10	2	29
29	1	34	4	34	5	02	2	49
30	1	23	4	43	4	53	3	09
31	1	12			4	44	3	29

Time. Apparent from the Subſtract Subſtract. Time * Apparent to the Add Add Time. Apparent Add to * Subſtract.

A New Correct Table for Equating of Time.

Days.	September		October.		November		December	
	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.
1	3	50	13	26	15	25	5	48
2	4	12	13	39	15	16	5	18
3	4	33	13	51	15	07	4	47
4	4	54	14	02	14	58	4	16
5	5	15	14	13	14	48	3	44
6	5	36	14	24	14	37	3	13
7	5	56	14	35	14	24	2	43
8	6	16	14	46	14	10	2	14
9	6	36	14	57	13	55	1	45
10	6	56	15	08	13	39	1	17
11	7	17	15	18	13	23	0	48
12	7	38	15	27	13	07	0	19
13	7	59	15	34	12	50	0	09
14	8	20	15	40	12	32	0	39
15	8	41	15	46	12	14	1	10
16	9	01	15	51	11	55	1	41
17	9	21	15	55	11	34	2	11
18	9	41	15	58	11	12	2	41
19	10	00	16	01	10	50	3	11
20	10	19	16	03	10	27	3	41
21	10	38	16	04	10	03	4	10
22	10	56	16	05	9	39	4	39
23	11	13	16	06	9	14	5	07
24	11	30	16	05	8	49	5	34
25	11	47	16	04	8	24	6	00
26	12	04	16	03	7	59	6	26
27	12	21	16	01	7	34	6	52
28	12	38	15	57	7	09	7	18
29	12	55	15	50	6	42	7	43
30	13	11	15	43	6	17	8	08
31			15	34			8	32

Time. Apparent from the Substract

Time. Apparent from the Substract

Time * Apparent to the Add from, &c.

A Table for the ſpeedy Converting the Hours Minutes and Seconds of Time, into Degrees and Minutes of the Equinoctial. And the Contrary, for turning Degrees and their Minutes into Time. *Mention'd in Page* 15.

Seconds of Time.	*Minutes of the Equator.*	*Minutes of Time.*	*Degrees and Min. of the Equ.*	*Hours of Time.*	*Degrees of the Equator*
Sec.	*Min.*	*Min.*	*deg. min.*	*Ho.*	*Degrees.*
4 =	1	1 =	0 . 15	1 =	15
8 =	2	2 =	0 . 30	2 =	30
12 =	3	3 =	0 . 45	3 =	45
16 =	4	4 =	1 . 00	4 =	60
20 =	5	5 =	1 . 15	5 =	75
24 =	6	6 =	1 . 30	6 =	90
28 =	7	7 =	1 . 45	7 =	105
32 =	8	8 =	2 . 00	8 =	120
36 =	9	9 =	2 . 15	9 =	135
40 =	10	10 =	2 . 30	10 =	150
44 =	11	20 =	5 . 00	11 =	165
48 =	12	30 =	7 . 30	12 =	180
52 =	13	40 =	10 . 00	&c.	
56 =	14	50 =	12 . 30		

The way of making Uſe of this Table is thus, ſuppoſe it were required to Convert or Change, 2 *Hours,* 43 *Minutes,* 38 *Seconds, into Degrees and Minutes of the Equinoctial.*

	Ho. Mi. Seat.		*Deg. Min. Sec.*	
Firſt	2 . 00 . 00 =		30 . 00 . 00	Add
And	40 . 00 =		10 . 00 . 00	
	3 . 00 =		0 . 45 . 00	
	36 =		0 . 09 . 00	
	2 =		0 . 00 . 30	
Hence	2 . 43 . 38 =		40 . 54 . 30	

As was Required. And ſo for the Contrary.